VI. EATON VORAD EVT-300 WITH SMARTCRUISE: THE SYSTEM

SYSTEM CONCEPTS

The Eaton Corporation is one of the largest suppliers of truck and automotive components in the United States. A major growth initiative for the company over the past decade has been its safety electronics subsidiary, Eaton VORAD.

The EVT-300 Collision Warning System (CWS) was introduced by Eaton VORAD in 1994. Its key goal was to provide early warnings of obstacles ahead, to increase driver reaction times and to reduce the number of rear-end collisions regardless of weather and lighting conditions. The system is marketed by Eaton to serve as a driver aid in rain, sleet, snow, fog, dust and darkness. The key advantages of the CWS concept for the driver are: awareness of safe following distance, conditioning to evaluate road hazards, improved recognition of hazards in inclement weather, and continuous peak performance at all hours in all conditions.

Figure 8. EVT-300 Driver Display Module

The VORAD system (Vehicle On-board RADar) uses a patented monopulse radar design to warn drivers of potential hazards in the road ahead such as stopped or slow-moving vehicles. The system also provides side blind-spot warnings. Options with the EVT-300 include a vehicle information management system, accident reconstruction, and an adaptive cruise control feature.

Large trucks have very long stopping distances even in ideal conditions, and driver reaction and response times are a crucial factor in many if not most tractor-trailer crashes. The EVT-300 provides driver-alert warnings for overtaking and lane-change movements, and Eaton estimates that 40 percent of all heavy truck crashes are rear-ending or sideswiping events.

Highway travel in winter storms is extremely hazardous, with poor visibility from blowing and drifting snow, as well as frosted windshields and frozen wiper blades. Risks are higher for rear-end or sideswipe crashes, and in a storm, stalled or slow-moving vehicles are a constant menace.

The EVT-300 radar system was already deployed nationally with several major transport fleets. The primary market in terms of volume was for heavy commercial trucks, but the CWS concept was a natural enhancement for specialty fleets, including maintenance and emergency vehicles.

ADOT already had experience with the VORAD concept through the application of the system by Caltrans, as discussed in the following section. Also, an EVT-300 had been installed in 2000 on the ADOT-3M snowplow, for evaluation in year-round operations on US 89 near Flagstaff and for comparison with the enhanced Caltrans CWS components.

ADOT EXPERIENCE WITH THE CALTRANS ROADVIEW SYSTEM

From the beginning, the Caltrans advanced snowplow research program incorporated collision warning as an integral element of the driver support system. The evolution of the CWS element of the Caltrans advanced snowplow is described in detail in three ASP and RoadView reports by the lead contractor, the Advanced Highway Maintenance & Construction Technology (AHMCT) Research Center at UC Davis (*see Bibliography*). This ATRC project report includes a brief overview of the Caltrans program efforts, for perspective.

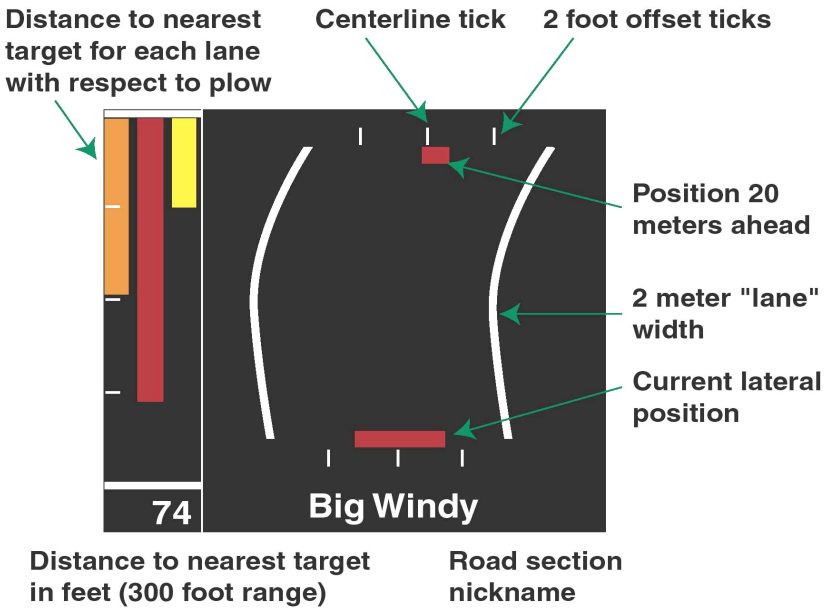

Figure 9. Caltrans RoadView Driver-Vehicle Interface Display

[Graphic courtesy of California PATH]

Caltrans initiated their advanced snowplow program as part of the preparations for the seminal San Diego Demo '97 activities. When ADOT-ATRC joined the ASP partnership in late 1997, discussions were still going on with regard to the best human-machine interface (HMI) approach for the original Caltrans ASP-I. Two ADOT snowplow operators participated with ATRC in a meeting with the Caltrans project team in Sacramento, to offer their perspectives on Arizona's operating practices, needs and constraints.

The ASP system design integrated collision warning radar into the HMI lane guidance display, using the left side of the screen to show the obstacle warning icons (Figure 9). As development progressed, the on-screen warning indicators evolved to moving tapes, or bars, ultimately showing target position, range, and rate of closure for up to three fixed or moving obstacles.

Off-the-shelf Eaton VORAD components were utilized to develop the CWS radar hardware used in the Caltrans system. Initially, the ASP-I had an EVT-200 antenna unit mounted at the center of the truck's radiator grille, positioned above the plow blade for a clear view of the roadway. Later on, the ASP-II and RoadView snowplow programs used twin EVT-300 antennas to provide binocular range and position data to the on-board system computer.

Constant development of this system by AHMCT over several years has focused on refining the accuracy and selectivity of the warnings. The goal was always to minimize the number of false or missed alerts and to maximize the consistency of timely, accurate target detections. Testing of the CWS in Arizona, as an integrated element of the ASP display, was a key program element in each winter of the joint evaluation program.

EVT-300 COLLISION WARNING SYSTEM DESIGN

The EVT-300 collision warning radar system employs an advanced Doppler radar design, operating at 24.725 Gigahertz, to monitor other vehicles and objects. The CWS system may be packaged at the customer's option with one or two side sensors to cover the driver's blind spots alongside the truck. Other options include the SmartCruise adaptive cruise control system, the Vehicle Information Management System, and an Accident Reconstruction data recording and recovery feature.

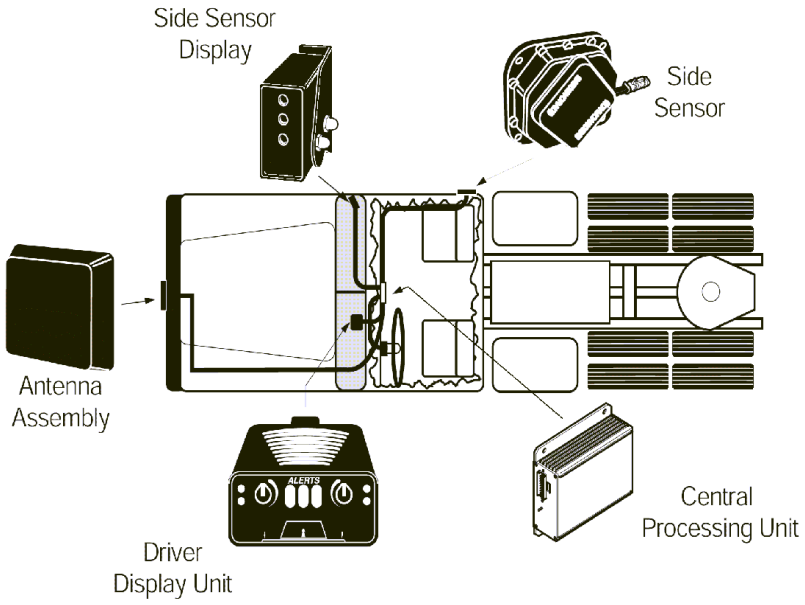

Figure 10. Schematic Diagram of the EVT-300 Collision Warning System

[Graphic by Eaton VORAD Technologies LLC]

The radar system has three major components, the antenna transceiver, the central processing unit, and the driver display unit. The optional side sensors have a separate display unit. The system employs monopulse radar technology with an effective range of 350 feet to accurately determine the distance, velocity and azimuth of multiple targets in the radar beam.

The primary antenna transceiver is normally mounted at bumper height on heavy trucks, and it transmits a flattened conical beam pattern that spreads five degrees vertically and twelve degrees horizontally. The added width of the beam accommodates roadway curvature. When traveling on a straight roadway, the processor filters out the warnings for objects that are outside of the 12 foot wide lane directly ahead of the vehicle. A gyroscope in the processor unit determines yaw rates relative to velocity as the vehicle moves through curves. With this turning rate data, the CWS processor can accurately shape the warning zone to the vehicle's curving trajectory. As forward motion returns to a straight path, the vehicle's yaw component becomes zero, and any new warnings are solely for the 12-foot travel lane straight ahead.

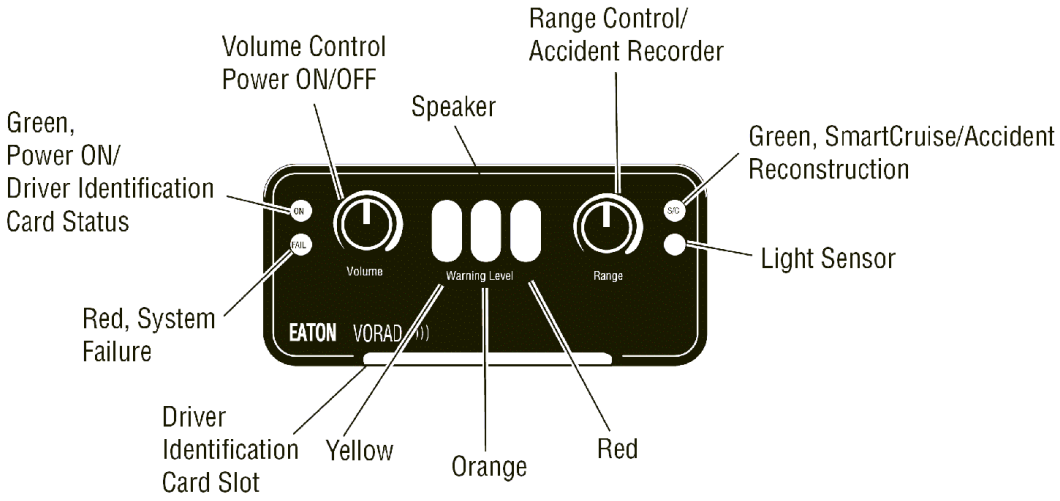

Figure 11. Driver Display Elements: EVT-300 Collision Warning System

[Graphic by Eaton VORAD Technologies LLC]

The EVT-300 employs a small driver display unit that is less than two inches high and four inches wide (Figures 8 and 11). It can be mounted on the dashboard, overhead, or as an integrated display. The optimal location is straight ahead of the driver, but different models of truck cabs have various space constraints. This driver display unit provides warnings with both colored lights and audible tones. As the distance to an obstacle decreases, three colored lights are progressively illuminated and multiple beeps or tones are sounded. Specific light and tone combinations also indicate system status.

The side sensor system option is equally sophisticated and will cover the critical blind spot(s) alongside a heavy truck. The side antenna transmits a conical 15-degree radar beam. The central processing unit filters the object warnings to just those between two and ten feet away, so as to cover only the lane next to the host vehicle. The side warning display unit is mounted on the windshield side pillar. It displays lights if objects are in range, but the audible tone is only

given if the truck's turn signal is activated. In the ADOT research application, one side sensor for the right side of the snowplow was installed, just aft of the cab, as shown in Figure 10.

The SmartCruise adaptive cruise control feature takes proximity warnings to the next level, by automatically responding to slower vehicles ahead. For truck models that have implemented Eaton VORAD software for use with their engines, SmartCruise can maintain a fixed separation interval of from 2.25 to 3.25 seconds of travel time, with the factory cruise control system.

With the truck's cruise control engaged, the EVT-300 assesses the relative speed and position of vehicles ahead, or those that cut in after passing. If the host vehicle is overtaking, SmartCruise reacts progressively through the engine control software by reducing fuel, by engaging the engine retarder, and then by downshifting the automatic transmission. ADOT has tested this feature.

Another key option of the EVT-300 is the Accident Reconstruction feature. This system stores up to 10 minutes of vehicle dynamics information in the central processing unit. This recorded data includes speed, trajectory and deceleration for not only the host vehicle, but for any other vehicles in the radar beam pattern. This data allows for better analysis of a crash event and can support claims investigations. The accident reconstruction feature must be activated manually after the event to save the data. The unit then must be sent to Eaton VORAD to access the data and print the accident reconstruction report. ADOT has not tested this feature.

One other significant documentation option of the EVT-300 is Eaton's Vehicle Information Management System. This feature monitors and records numerous vehicle system data types including engine run time, driving time, fuel economy, average and peak speeds, hard braking, and time on brakes. It also can report from the radar data how much time the truck is following within one-half to three seconds of the vehicle ahead. This data is accessible by the fleet manager with Windows™-based software. ADOT has not tested this feature.

EVT-300 SYSTEM LIMITATIONS

The EVT-300 Driver Reference Manual contains a number of cautions for safe use of both the basic CWS and the SmartCruise. The systems are clearly defined as driving aids for the alert and conscientious professional driver. The primary factors in deploying the EVT-300 are training and commitment. When the system is properly installed and calibrated, a focused effort by the individual driver is required to learn to safely and efficiently use the system. The driver must be able to interpret the warnings confidently and correctly as to the urgency and type of hazard, and he must react quickly to the progressive series of warnings as shown in Figure 12.

Another concern is false warnings or missed alerts. The narrow twelve-foot lane warning zone allows situations where the radar response may be affected by gradual curves, dips and hills. There may also be inconsistencies at the transition from straight to curved roadway. Similarly, there may be false radar warnings from overhead signs or fixed objects near the shoulder.

Animals and pedestrians are an area of constant concern for drivers, and Eaton literature warns of possible missed alerts. The design focus of the system is for moving and/or stationary targets with some steel or aluminum present, such as the frame or chassis. The forward radar can detect people and animals if they are of the correct mass to reflect the Doppler radar signal, but it is not intended for that application.

Eaton VORAD states that there is no guarantee that the radar will see all people or animals, and it should not be used solely to detect animals in the roadway. Animals (elk, deer, etc.) moving perpendicular to the beam across the road at a fast rate of speed may not be consistently detected, as they are only in the radar beam detection zone for a brief period with no good reflection of the radar signal. The EVT-300 is designed to only warn of objects ahead within the 12 foot-wide travel path of the vehicle, to minimize false alerts.

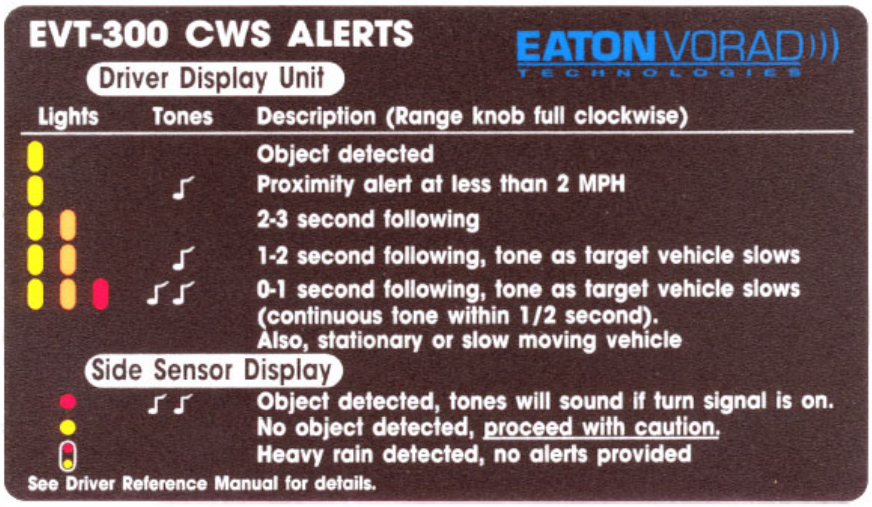

Figure 12. EVT-300 Collision Warning Alert Sequence

[Graphic by Eaton VORAD Technologies LLC]

Overall, a higher level of focus, training, practice and experience are required for drivers to rely fully on the EVT-300, and to interpret and respond quickly and properly in a warning situation.

EVT-300 SYSTEM COST DETAILS

The project acquired four of the collision warning radar system retrofit kits. The first unit was purchased in 2000, with three more in late 2002. The latter units, with one side sensor, were purchased directly from Eaton VORAD for approximately $2,400 each. There were also some Eaton technical support charges to help install and commission the three new systems on similar but not identical snowplows. ADOT shop charges averaged around $500 for each unit installed.

Originally, the first Eaton VORAD EVT-300 was installed on F342, the ADOT-3M research snowplow at Gray Mountain. This was the only snowplow that was considered for testing of the SmartCruise system. While that system upgrade had a cost of $250, ADOT also had to acquire and install a second bumper-mount antenna and wiring loom for summer tests with SmartCruise. There were also a number of issues to work out with Mack Truck to enable the engine control software to function correctly. These research-related costs are not relevant to a standard installation and so are not listed here. The project's cost for a standard system with one side sensor, as installed by ADOT shop crews, was approximately $3,000.